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(54) **Apparatus and method for precise velocity control**

(57) An apparatus and method for precisely controlling a driven component (10) in an electromechanical system, particularly for controlling the speed of a photoreceptor or intermediate transfer belt in an electrophotographic printing machine. A sensor (160) monitors the speed of the driven belt (10) and generates and sends a signal indicative thereof to a controller (90). A second sensor monitors the rotational speed of the shaft (172) of the drive motor (170) and also generates a signal indicative thereof and sends that signal to the controller (90). The controller (90) processes the signals so that a preselected belt speed is maintained while minimizing or eliminating torque disturbances caused by the rapid fluctuation of the motor velocity without the necessity of using an inertial flywheel.

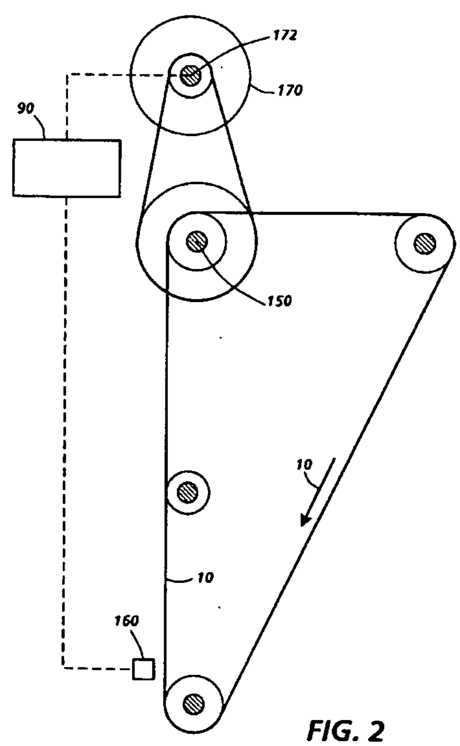

FIG. 2

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Description

This invention relates generally to an electrophotographic printing machine, and more particularly concerns an improved method and apparatus for controlling the lateral movement of a moving belt.

In a typical electrophotographic printing process, a photoconductive member in the form of a drum used in combination with an intermediate transfer medium may be employed. Belt type photoreceptors can also be used, alone or in combination with either an intermediate transfer belt or an intermediate transfer drum.

U.S.-A-5,204,602 describes a servo motor control method capable of automatically affecting optimum backlash acceleration correction under various machine operating conditions. A backlash acceleration correction process is started when the sign of a positional deviation is inverted, and is cyclicly executed thereafter. A cutting speed is estimated from the square root of the positional deviation at the start of the correction process, and a constant, used to calculate a backlash acceleration amount, and a backlash acceleration time are calculated in accordance with the estimated cutting speed. By inverting the sign of the output of an integrator of a speed loop, moreover, a target value is obtained which is equal in magnitude to the integrator output and whose sign is opposite to that of the integrator output. In each processing cycle, the product of the constant and the difference between the target value and the present integrator output is obtained, and a torque command to be used for the drive control of the servo motor is obtained in accordance with the speed command after the backlash acceleration correction, which is obtained by adding the resultant product to a speed command calculated in a position loop process.

U.S.-A-5,073,746 discloses a speed control method for a servo motor capable of smoothly rotating the servo motor without causing pulsating rotation even when the servo motor rotates at low speeds. On the basis of numbers f feedback pulses detected and stored at intervals of a period equal to a value obtained by dividing an estimated speed calculation period by an integer multiple of two, the number of feedback pulses in each estimated speed calculation period and the number of pulses in a time period from a mid point of an estimated speed calculation period immediately before each estimated speed calculation period to a mid point of each estimated speed calculation period are calculated, and an estimated speed indicative of an actual rotation speed of the servo motor is further calculated on the basis of the calculated numbers of pulses.

The exists a need for a system for precisely controlling the speed and/or position of a rotating photoreceptor member in a printing device, particularly in multicolour printing machine, where accurate registration of successively formed individual colour images is of great importance.

In accordance with one aspect of the present invention, there is provided an apparatus for controlling the velocity of a motor driven component. The apparatus comprises a first sensor adapted to detect the velocity of the driven component and generate a first signal indicative thereof, a second sensor adapted to detect the velocity of the motor and generate a second signal indicative thereof, and a controller, responsive to the first signal and the second signal, for generating a motor control signal.

Pursuant to yet another aspect of the present invention, there is provided an electrophotographic printing machine comprising an apparatus as set forth above and a motor operatively connected to the driven component.

Pursuant to another aspect of the present invention, there is provided a method for controlling the velocity of a motor driven component. The method comprises detecting the velocity of the driven component and generating a first signal indicative thereof, detecting the velocity of the motor and generating a second signal indicative thereof and generating a motor control signal as a function of the first signal and the second signal.

Pursuant to yet another aspect of the present invention, there is provided a programmable electrophotographic printing machine comprising a motor operatively connected to a driven component, the machine being suitably programmed for carrying out the method as set for above, or according to any of the embodiments described herein.

Other features of the present invention will become apparent as the following description proceeds and upon reference to the drawings, in which:

Figure 1 is a graphical representation of the registration errors for various frequencies of motor torque disturbance;

Figure 2 is a schematic representation of a photoreceptor drive system in a multicolor electrophotographic printing machine;

Figure 3 is a flow diagram illustrating the method of the present invention to precisely control the speed of a electromechanical system;

Figures 4A and 4B are graphical comparisons of the torque response curve with and without the control system of the present invention; and

Figure 5 is a schematic elevational view depicting an illustrative multicolor electrophotographic printing machine incorporating the apparatus of the present invention.

For a general understanding of the features of the present invention references are made to the drawings. In the drawings, like reference numerals have been used throughout to designate identical elements.

Referring initially to Fig. 5, an intermediate belt designated generally by the reference numeral 10 is mounted rotatably on the machine frame. Belt 10 rotates in the direction of arrow 12. Four imaging reproducing stations

indicated generally by the reference numerals 14, 16, 18 and 20 are positioned about the periphery of the belt 10. Each image reproducing station is substantially identical to one another. The only distinctions between the image reproducing stations is their position and the color of the developer material employed therein. For example, image reproducing station 14 uses a black developer material, while stations 16, 18 and 20 use yellow, magenta and cyan colored developer material. Inasmuch as stations 14, 16, 18 and 20 are similar, only station 20 will be described in detail.

At station 20, a drum 22 having a photoconductive surface deposited on a conductive substrate rotates in direction of arrow 24. Preferably, the photoconductive surface is made from a selenium alloy with the conductive substrate being made from an electronically grounded aluminum alloy. Other suitable photoconductive surfaces and conductive substrates may also be employed. Drum 22 rotates in the direction of arrow 24 to advance successive portions of the photoconductive surface through the various processing stations disposed about the path of movement thereof.

As the various processing stations of the machine of Fig. 5 are known in the art, a detailed description thereof has been omitted from the present disclosure, for brevity. For further details, reference is made to US application S.N. 08/343,394, a copy of which was filed with the present application.

The various machine functions are regulated by controller 90. The controller is preferably a programmable microprocessor which controls all of the machine functions described herein. The controller provides a comparison count of the copy sheets, the number of documents being recirculated, the number of copy sheets selected by the operator, time delays, jam corrections, etc.. The control of all of the exemplary systems heretofore described may be accomplished by conventional control switch inputs from the printing machine consoles selected by the operator. Conventional sheet path sensors or switches may be utilized to keep track of the position of the document and the copy sheets.

Depending upon the specifics of a particular application, the pass to pass process direction registration specification on a photoreceptor module for multiple exposure color (either single pass or multi pass) generally ranges from 15 to 60 μm for the photoreceptor process direction. Key to the strategy to achieve this level of registration is to limit the photoreceptor errors to be identical for each color separation. That is, whatever motion nonuniformities occur during the production of the image in the first color must be repeated for all of the other colors, thus eliminating any relative motion and misregistration. This requires that the photoreceptor motion errors be synchronous with the image to image spacing.

By proper sizing of the photoreceptor roll diameters, they can be made to rotate an integer number of times as the photoreceptor travels from one imaging zone to another. If this is accomplished, the run out errors of the rolls which affect the photoreceptor motion quality will not generate registration errors. This property of synchronism permits a reasonable tolerance to be placed on the drive elements physical dimensions but also puts restrictions on the drive element physical size and image to image spacing.

Although the strategy of incorporating synchronism allows relaxation of the run out specification, there is a problem with the periodic higher frequency of the motor torque disturbance and its harmonics. This is true because even though the circumference of a roll turning at 3 hertz, for example, may be only a few degrees out of phase for rotation with respect to the image pitch, resulting in very little registration error, the 8 hertz, 16 hertz, and higher frequency disturbances produced by the motor will be much more out of phase, resulting in a larger registration error. These errors are illustrated graphically in Figure 1. Using the shaded area corresponding to registration error under the lowest frequency pulse as a reference of 1, the mid frequency error would be 3.7, and the high frequency error would be 4.9.

Due to the phase problem, the magnitude of the disturbances must be made as small as possible at higher frequencies. One way of reducing certain of these disturbances is to feed back the motor velocity in addition to the surface velocity. A second way to reduce the magnitude of these disturbances is to add an inertia flywheel on the motor output drive shaft. However, adding an inertia flywheel requires additional space and size that puts severe restrictions on the design for new printing machines. Thus, if the torque disturbances can be minimized or eliminated without the use of the inertia flywheel, a smaller more compact printing machine can be designed.

Turning now to Figure 2, there is illustrated a schematic representation of an intermediate belt drive system of Figure 5 utilizing the velocity control of the present invention. In the illustrated system, the belt 10 moves in the process direction indicated by arrow 12 through various processing stations. The belt 10 is driven by drive roll 150 which is connected to a drive motor 170. The velocity control system utilizes a speed sensor 160 to detect the surface velocity of the intermediate belt 10. A second speed sensor (not shown), preferably in the form of a rotary encoder, is used on the output shaft 172 of the drive motor 170 to accurately measure the rotational speed of the drive motor output shaft 172. Of course, the control system described can also be used to control photoreceptor drums or belts in printing machines utilizing an intermediate transfer media or in direct image on image recording systems.

Figure 3 illustrates a flow chart of the servo control system utilized for the velocity control system herein. The servo system utilizes a two loop feedback system: in the first lop 302 the surface velocity of the photoreceptor 10 is fed back into the main velocity controller 90; and a secondary motor 170 velocity feedback loop 304

is utilized to additionally reduce velocity errors due to motor torque disturbances. This dual feedback loop is found to be particularly effective at reducing motor torque disturbances and can minimize or eliminate the need for an inertia fly wheel to reduce velocity error due to motor torque disturbances.

Figures 4A and 4B graphically illustrate two torque response curves. Figure 4A illustrates a torque response curve utilizing a photoreceptor 10 drive system without the velocity control system of the invention herein. This measure of the system performance desribes the motion of the driven component ratioed to the amount of torque fluctuation at the motor 170. Figure 4B illustrates the torque response curve utilizing the dual feedback system of Fig. 3. It can be seen that there is a two to three time improvement of the torque disturbance at the 8 Hz and 16 Hz response points. The 8 and 16 Hz frequencies are indications of motor torque error frequencies. This improvement will result in a proportional improvement in the magnitude of the photoreceptor velocity variation due to torque variations of the motor at its fundamental frequency in its first harmonic. This in turn will proportionally reduce the corresponding registration errors caused by the asynchronicity in the system.

In recapitulation, there is provided an apparatus and method for precisely controlling a driven component in an electromechanical system, particularly for controlling the speed of a photoreceptor or intermediate transfer belt in an electrophotographic printing machine. A sensor monitors the speed of the driven belt and generates and sends a signal indicative thereof to a controller. A second sensor monitors the rotational speed of the drive motor for the component and also generates a signal indicative thereof and sends that signal to the controller. The controller processes the signals so that a preselected belt speed is maintained while minimizing or eliminating torque disturbances caused by the rapid fluctuation of the motor velocity without the necessity of using an inertial flywheel.

Claims

1. An apparatus for controlling velocity of a component (10) driven by a motor (170), comprising:

   a first sensor (160) adapted to detect the velocity of the driven component (10) and generate a first signal indicative thereof;
   a second sensor adapted to detect the velocity of the motor (170) and generate a second signal indicative thereof; and
   a controller (90), responsive to the first signal and the second signal, for generating a motor control signal.

2. An apparatus according to claim 1, wherein said first sensor (160) comprises a photoemitter-photoreceptor pair.

3. An apparatus according to claim 1 or 2, wherein said second sensor comprises an optical rotary encoder.

4. An apparatus according to claim 1 or 2, wherein said second sensor comprises a magnetic rotary encoder.

5. An electrophotographic printing machine, comprising an apparatus according to any of claims 1 to 4 and a motor (170) operatively connected to the driven component (10).

6. A printing machine according to claim 5, wherein the driven component (10) comprises a photoreceptor belt.

7. A printing machine according to claim 5, wherein the driven component (10) comprises an intermediate transfer belt.

8. A method for controlling the velocity of a motor driven component (10) of an electromechanical system, comprising:

   detecting the velocity of the driven component (10) and generating a first signal indicative thereof;
   detecting the velocity of the motor (170) and generating a second signal indicative thereof; and
   generating a motor control signal as a function of the first signal and the second signal.

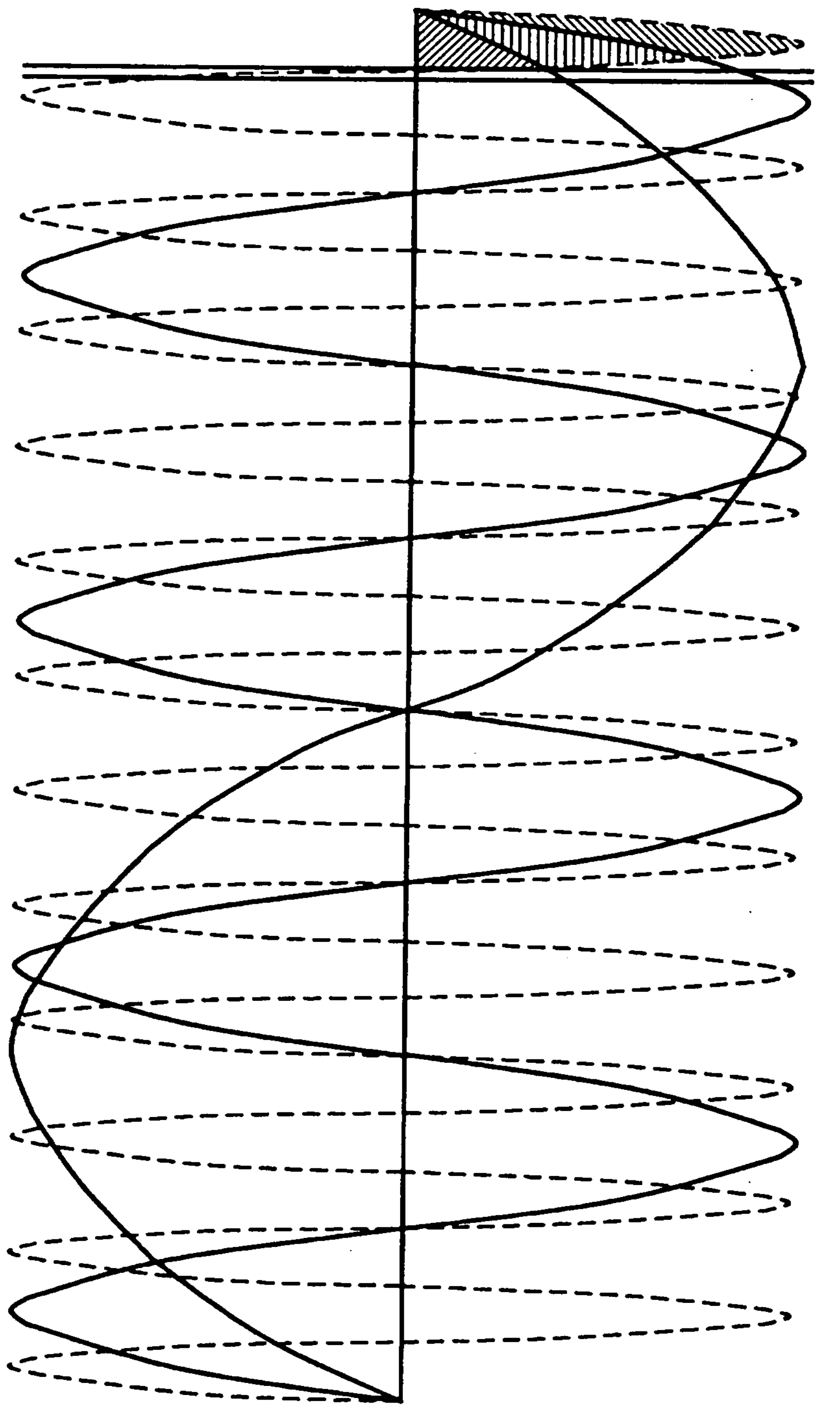


FIG. 1

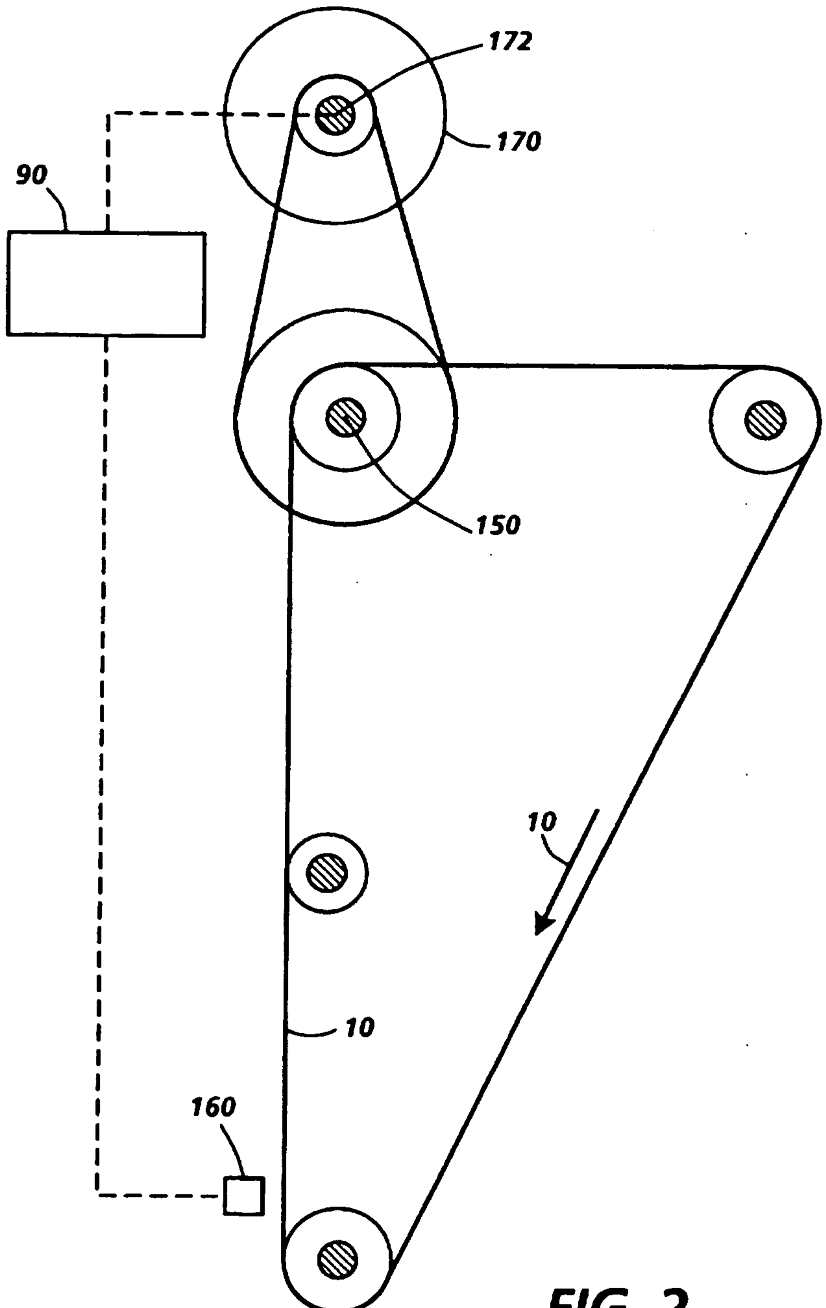


FIG. 2

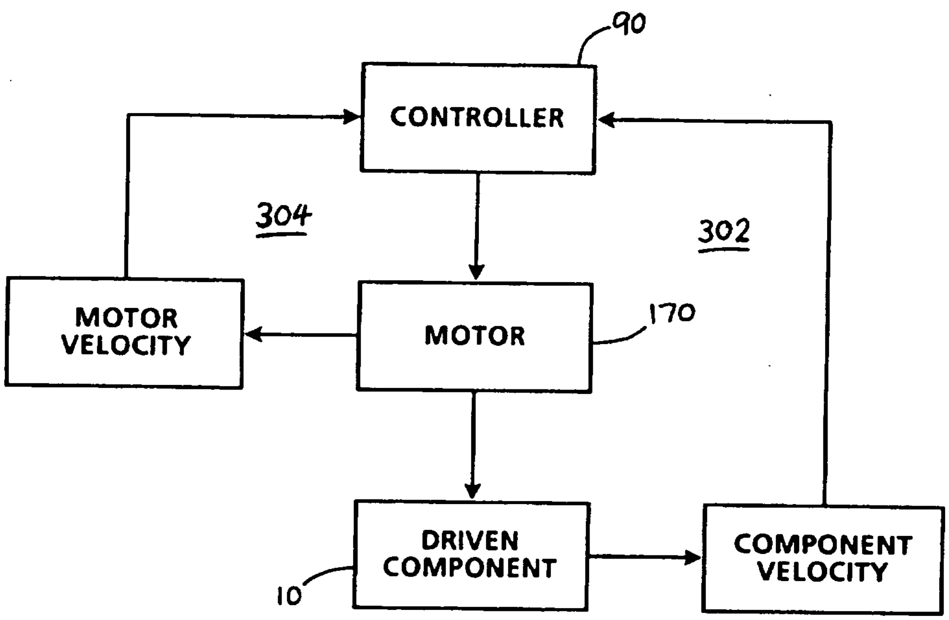

90
CONTROLLER
304
302
MOTOR VELOCITY
MOTOR
170
DRIVEN COMPONENT
10
COMPONENT VELOCITY

FIG. 3

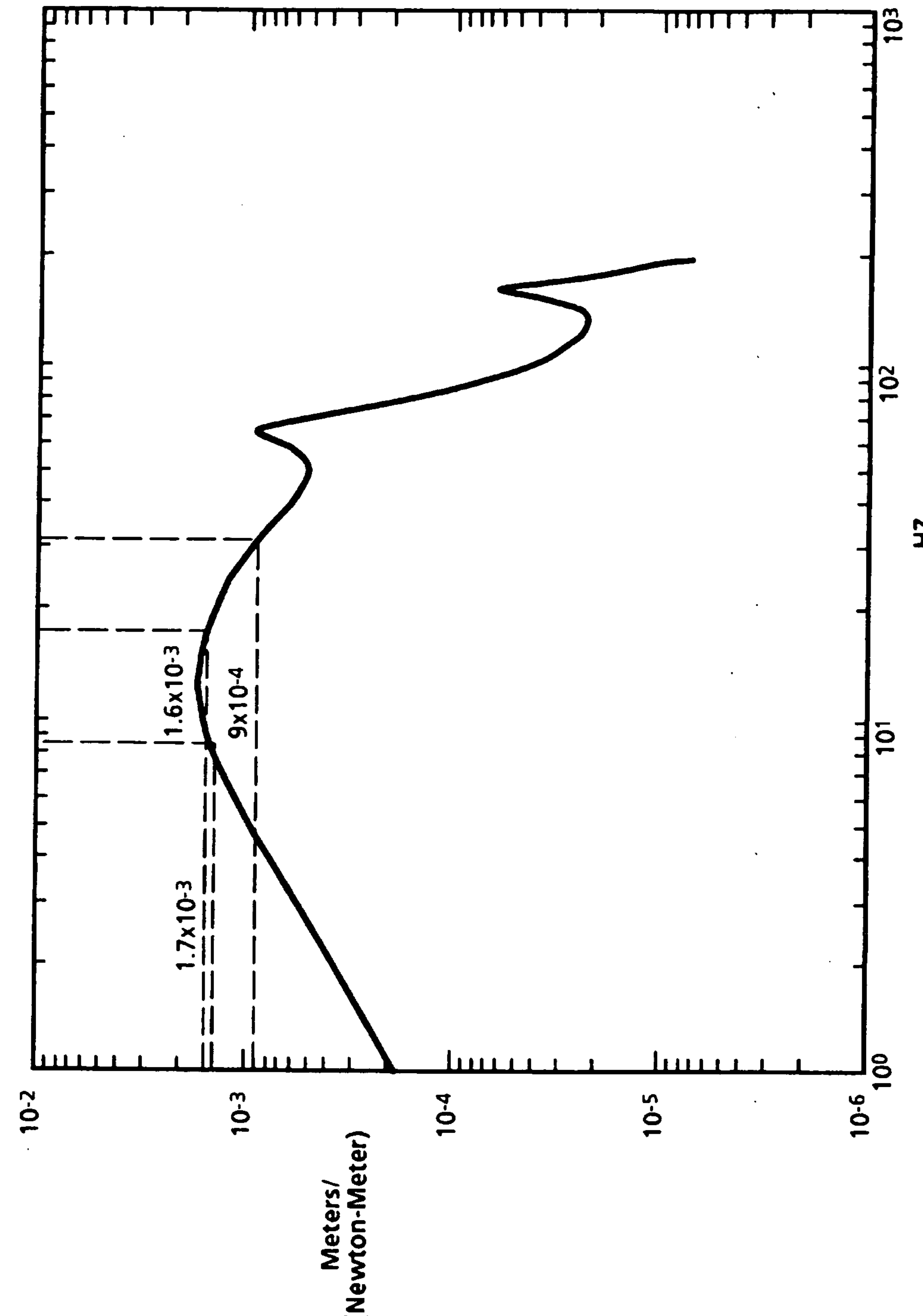
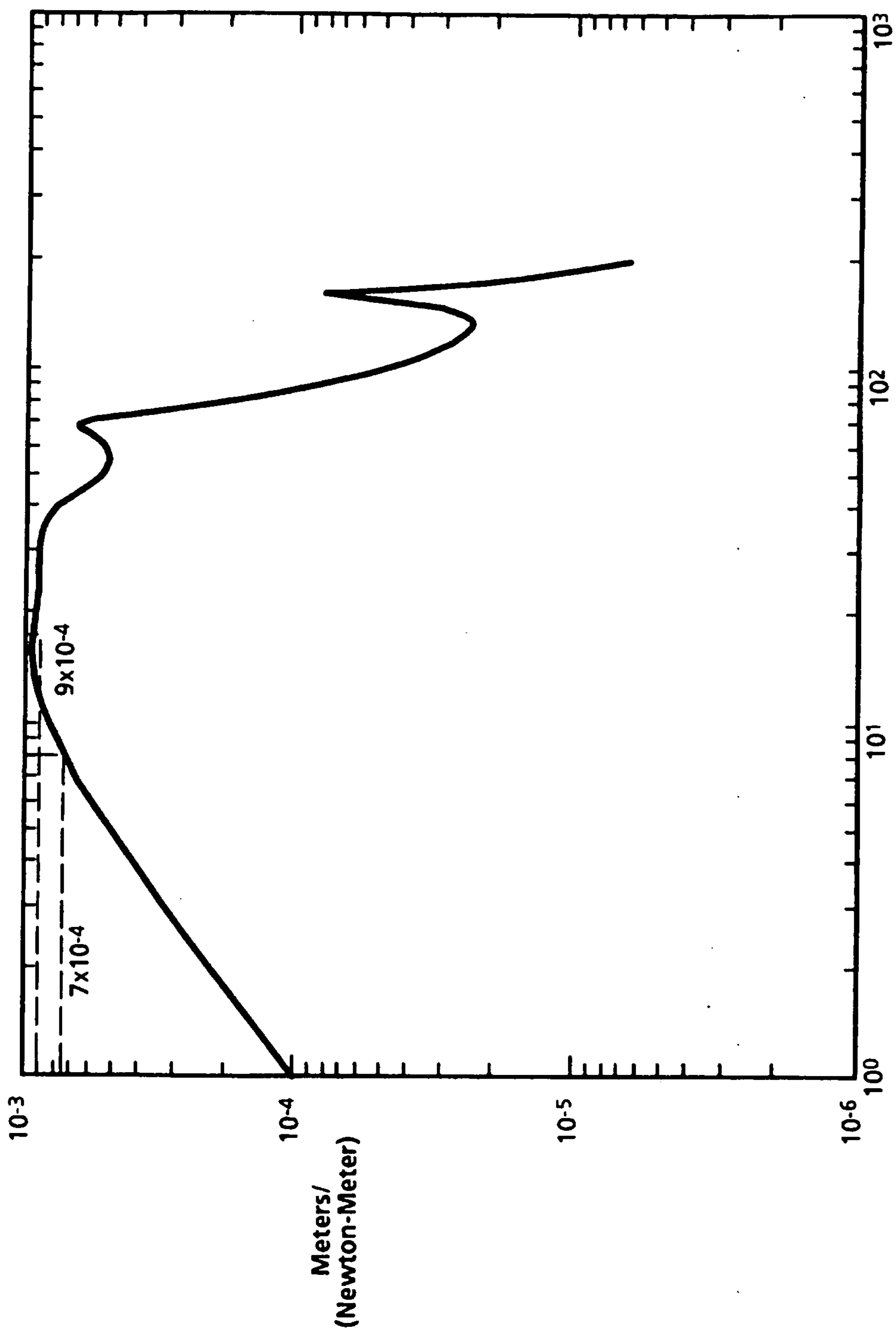

Meters/
(Newton-Meter)
10-2
10-3
10-4
10-5
10-6
100
101
102
103
HZ
1.7x10-3
1.6x10-3
9x10-4

FIG. 4A


10-3
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Meters/
(Newton-Meter)
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101
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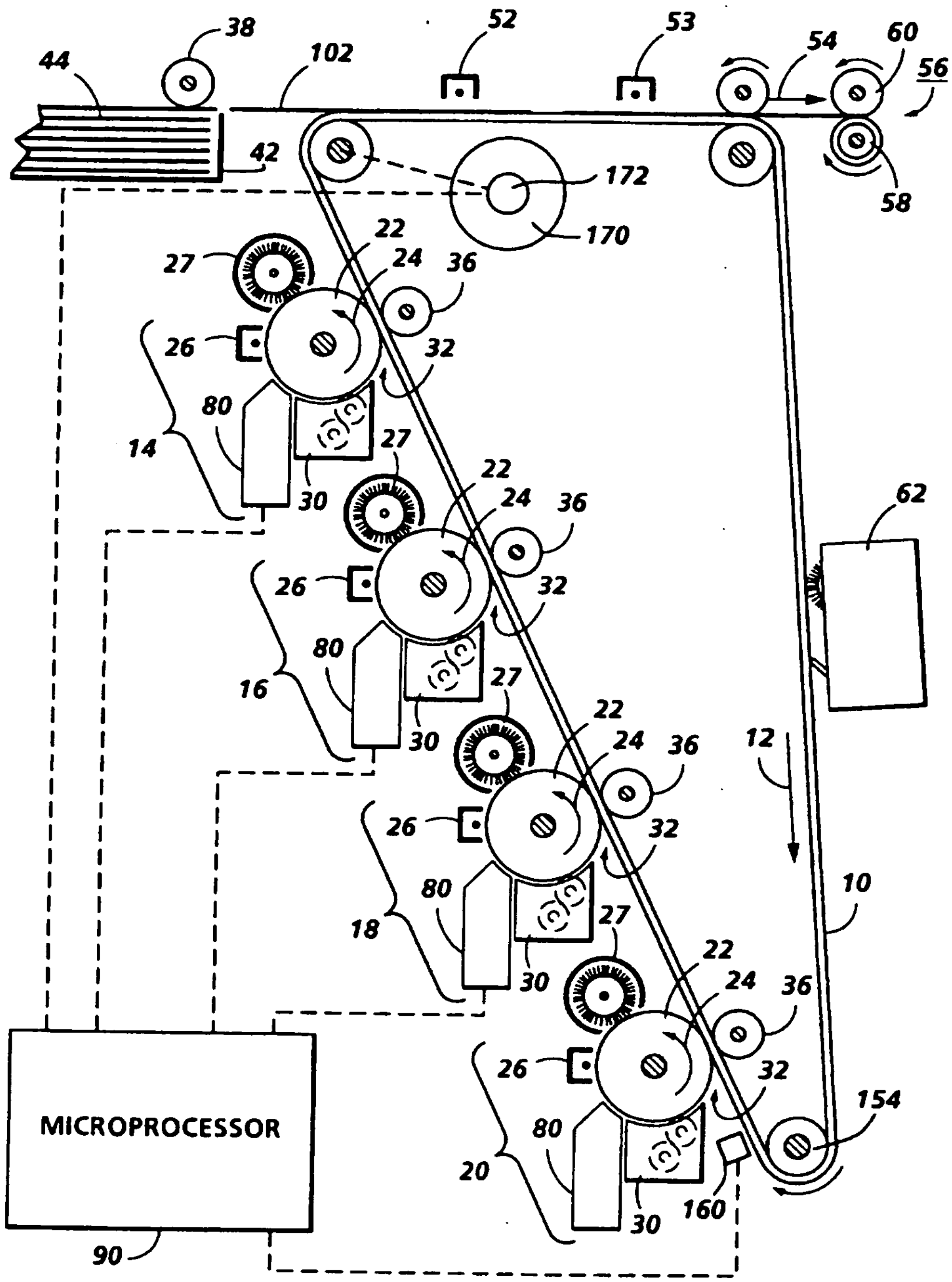
103
HZ
9x10-4
7x10-4

FIG. 4B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12
26
32
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18
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22
24
36
26
32
MICROPROCESSOR
154
80
20
160
30
90
62

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 95 30 8369

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	EP-A-0 349 975 (PFISTER GMBH) 10 January 1990 * abstract; figure 1 *	1-4 5-8	H02P5/00 G03G15/00 G03G15/16
X Y	SOVIET INVENTIONS ILLUSTRATED Section EI, Week 8809 Derwent Publications Ltd., London, GB; Class X25, AN 88-062157 & SU-A-1 320 137 (KRIV MINE INST) , 30 June 1987 * abstract *	1-4 5-8	
X Y	FUJIKAWA K ET AL 'ROBUST AND FAST SPEED CONTROL FOR TORSIONAL SYSTEM BASED ON STATE-SPACE METHOD' 28 October 1991 , PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON INDUSTRIAL ELECTRONI CONTROL AND INSTRUMENTATION (IECON), KOBE, OCT. 28 - NOV. 1, 1991, VOL. 1 OF 3, PAGE(S) 687 - 692 , INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS * page 687, paragraph 2 * * page 691, paragraph 5; figure 6 *	1-4 5-8	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H02P G03G
X Y	US-A-5 101 145 (REHM THOMAS) 31 March 1992 * column 1, line 9 - line 68 *	1-4 5-8	
Y	PATENT ABSTRACTS OF JAPAN vol. 012 no. 313 (P-749) ,25 August 1988 & JP-A-63 081371 (CANON INC) 12 April 1988, * abstract *	5-8	
A	PATENT ABSTRACTS OF JAPAN vol. 009 no. 167 (P-372) ,12 July 1985 & JP-A-60 042771 (FUJI XEROX KK) 7 March 1985, * abstract *	5,8	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 February 1996	Bourbon, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

Application Number
EP 95 30 8369

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US-A-4 914 726 (BURKE EDWARD F) 3 April 1990 * the whole document * -----	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

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